PAPR Reduction using DFT Spreading with FEC for OFDM Systems

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***Abstract*: The next generation of mobile communication is based on OFDM technology. It is an efficient method of data transmission for high speed communication system. Orthogonal frequency division multiplexing (OFDM) systems have been proposed in the recent past years for providing high spectral efficiency, less vulnerability to echoes, low implementation complexity and resistance to non linear distortion .However the main drawback of OFDM system is high peak to average power ratio (PAPR) of transmitted signals due to inter-symbol interference between the subcarriers as a result the amplitude of such a signal can have high peak values. Thus a power amplifier must be carefully manufactured to have a linear input output characteristics or to have large input output back-off. Drawback of high PAPR is that dynamic range of power amplifier and Digital to Analog (D/A) converter during the transmission and reception of the signal is higher. As a result total cost of transceiver increases with reduced efficiency. Discrete Fourier Transform (DFT) Spreading is one of the schemes to reduce the PAPR problem in OFDM system by using different subcarrier mapping schemes. In this paper we proposed combination of DFT spreading technique with FEC coding to reduce PAPR in OFDM system. Performance evaluation carried out in terms of SNR (signal to noise ratio) BER (bit error rate).**

***Keywords:* MIMO OFDM, Peak to average power ratio (PAPR), Discrete Fourier Transform (DFT), IFDMA, DFDMA, LFDMA, FEC, Viterbi decoding.**

I. INTRODUCTION

Nowadays, the demand for multimedia data services has grown up rapidly. One of the most promising multi-carrier systems, Orthogonal Frequency Division Multiplexing (OFDM) is basis for all 4G wireless communication systems due to its large capacity to allow the number of subcarriers, high data rate and ubiquitous coverage with high mobility [1]. It effectively combats the multipath fading channel and improves the bandwidth efficiency. At the same time, it also increases system capacity so as to provide a reliable transmission. OFDM uses the principles of Frequency Division Multiplexing (FDM) [2]. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers [3]. These subcarriers are overlapped with each other. Inter-symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol [3]. An OFDM signal consists of a number of independently modulated subcarriers, which can give a large peak to average power ratio and these subcarriers are mutually orthogonal that’s why its name occur as orthogonal frequency division multiplexing[4]. OFDM is a combination of modulation and multiplexing. OFDM is a multicarrier system which uses Discrete Fourier Transform (DFT) or Fast Fourier Transform (FFT) [5]. OFDM system has many advantages but it also suffers from the disadvantages, like sensitive to time and frequency synchronization errors, high value of peak-to-average power ratio (PAPR), inter carrier interference (ICI) and co-channel interference (CCI). Cyclic prefix (CP) is added at the beginning of each OFDM symbol which is a repetition of the last part of an OFDM symbol [6]. In order to reduce the PAPR in OFDM systems, there are several techniques developed such as Clipping and Filtering, Selected Mapping (SLM), Partial Transmit Sequence (PTS), Interleaving Technique, Tone Reservation (TR), Tone Injection (TI), Peak Windowing, DFT Spreading [7]. However, all of the above methods have some limitations. In this paper, we propose a PAPR reduction technique using modified DFT Spreading technique with FEC coding. This paper is organized as follows: In section II, concept of PAPR in OFDM system, Proposed method is explained in section III. Simulation results and discussions are given in section V. Finally we will conclude in section VI.

II. PAPR OF OFDM SYSTEM

A. OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using subcarriers which are orthogonal to each other. In OFDM, a block of N symbols is transmitted over N sub-carriers parallel. OFDM modulation is done with the help of IFFT. The complex representation of OFDM signal is given as:

$$x(k) = \frac{1}{N}\sum_{n=0}^{N-1} X_n\, e^{j2\pi n\frac{k}{N}} \text{ ; k=0, 1, ..., N-1}$$

B. PAPR Problem

PAPR(peak average power ratio) is the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. It occurs when in a multicarrier system the different sub-carriers are in phase or out of phase with each other. When all the points achieve the maximum value simultaneously; this will cause the output envelope to suddenly shoot up which causes a 'peak' in the output envelope. PAPR is defined as:-

$$PAPR = 10log_{10}\frac{P_{peak}}{P_{average}} \text{ (dB)}$$

A high peak to average power ratio causes saturation in power amplifiers, leading to inter modulation products among the sub carriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR. There are several techniques to reduce PAPR in a OFDM system. In this paper we use DFT-spreading technique to reduce PAPR.

III. PROPOSED METHOD

A. DFT-SPREADING TECHNIQUE

In the fig.1 OFDMA system, let DFT of the same size as IFFT is used as a (spreading) code. As the DFT and the IDFT operations virtually cancel each other, our OFDMA system becomes equivalent to the Single Carrier FDMA (SC-FDMA) system.

Thus the transmitted signal will have the same PAPR as that of the Single Carrier FDMA system.

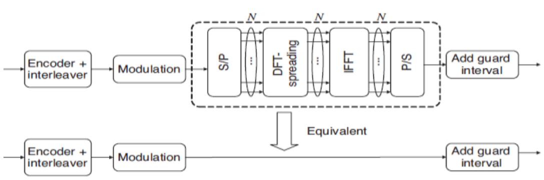


Fig.1.DFT technique model

As given in fig.2 the subcarriers can be assigned among the users in two different ways: DFDMA (Distributed FDMA) and LFDMA (Localized FDMA).

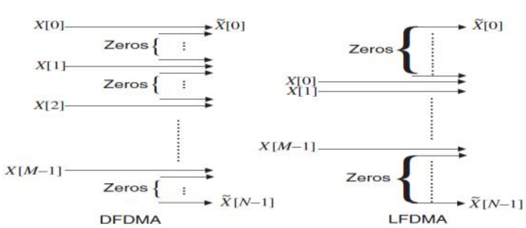


Fig.2. Subcarrier mapping in OFDMA system: DFDMA and LFDMA

In fig.2. DFDMA distributes M DFT outputs over the entire band (of total N subcarriers) with zeros filled in (N-M) unused subcarriers. LFDMA allocates DFT outputs to M consecutive subcarriers in N subcarriers. When DFDMA distributes DFT outputs with equi-distance N/M=S, it is referred to as IFDMA (Interleaved FDMA) where S is called the bandwidth spreading factor.

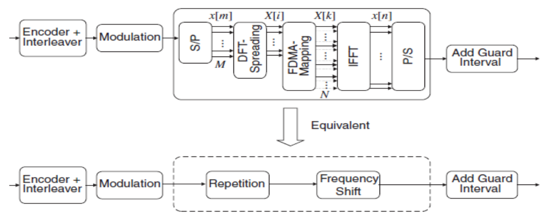


Fig.3. Uplink transmitter with DFT-spreading technique of IFDMA

Fig.3 shows a block diagram of the uplink transmitter with the DFT-spreading technique employing IFDMA. Here, the input data x[m] is DFT-spread to generate X[i] and then allocated as:

$$\tilde{x}[k] = \begin{cases} X\left[\frac{k}{S}\right], k = S.m1, m1 = 0,1,2,\ldots\ldots, M-1 \\ 0 \quad \text{, otherwise} \end{cases}$$

The IFFT output sequence $\tilde{x}[n]$with n=M. s+ m for s=0,1,2,......., S-1 and m =0,1,2, ..., M-1 can be expressed as

$$\tilde{x}[n] = \frac{1}{N}\sum_{k=0}^{N-1}\tilde{X}[k]e^{j2\pi\frac{n}{N}k}$$

$$= \frac{1}{S}\frac{1}{M}\sum_{m1=0}^{M-1}X\,[m1]e^{j2\pi\frac{n}{M}m1}$$

$$= \frac{1}{S}.\frac{1}{M}\sum_{m1=0}^{M-1}X[m1]e^{j2\pi\frac{MS+m}{M}m1}$$

$$= \frac{1}{S}.x[m]$$

Here the repetition of the original input signal $x[m]$ scaled by 1/S in the time domain occurs.

Similarly, if the subcarrier mapping starts with the rth subcarrier (r=0, 1, 2, 3, ..., S-1) in IFDMA, then the IFFT output-sequence, $\{\check{x}[n]\}$ is given by $\frac{1}{S}e^{j2\pi\frac{n}{N}r}$.x[m] i.e. there is a phase rotation of $e^{j2\pi\frac{nr}{N}}$ in IFDMA.

B. FORWARD ERROR CORRECTION (FEC)

FEC technique allows automatic correction of errors. This method incorporates convolutional encoding with viterbi decoding. The performance of FEC technique is characterized for an AWGN channel. Convolutional encoding is one way of performing channel coding in the transmitter where as in the receiver; Viterbi decoding is a way of performing channel decoding. A convolutional encoder accepts a sequence of message symbols and produces a sequence of code symbols.

In Viterbi decoding, the Viterbi decoder examines an entire received sequence of a given length. The decoder computes a metric for each path and makes a decision based on this metric. When two paths coverage on one node, only one survivor path is chosen based on a decision. This decision can be achieved in two ways, resulting in the following two types of Viterbi decoding:

1. Hard decision Viterbi decoding
2. Soft decision Viterbi decoding

***Hard Decision Viterbi Decoding:** It is also referred to as the soft input Viterbi decoding technique; this uses a path metric called the Hamming Distance metric, to determine the survivor paths as we move through the trellis. Hard decision Viterbi decoding makes use of the maximum hamming distance in order to determine the output of the decoder.

The working of the Hard decision Viterbi decoder almost follows the same principle as that of the Soft decision Viterbi decoder. The only difference is that of the calculation of the path metrics. Here in this paper we have used Hard decision Viterbi decoding.

IV.SIMULATION RESULTS

In the following simulation results, we compared LFDMA and IFDMA with OFDMA and their performance in PAPR reduction. Below figure shows the performance of PAPR with different no of subcarriers and different modulation techniques like 16 QAM, 64 QAM and 256 QAM.

Figure number	No of subcarrier	No of symbol	PAPR of OFDMA in dB			PAPR of SC-FDMA in dB					
						LFDMA			IFDMA		
			16 QAM	64 QAM	256 QAM	16 QAM	64 QAM	256 QAM	16 QAM	64 QAM	256 QAM
4(a)	64	64	11.6	10.8	11.2	3.6	4.8	5.4	3.8	4.8	5.2
4(b)	256	64	11	10.6	10.8	8.2	8.2	9.2	3.4	4.6	5.2
4(c)	256	128	10.2	9.6	10	8.2	7.8	8	3.2	4.2	4.6

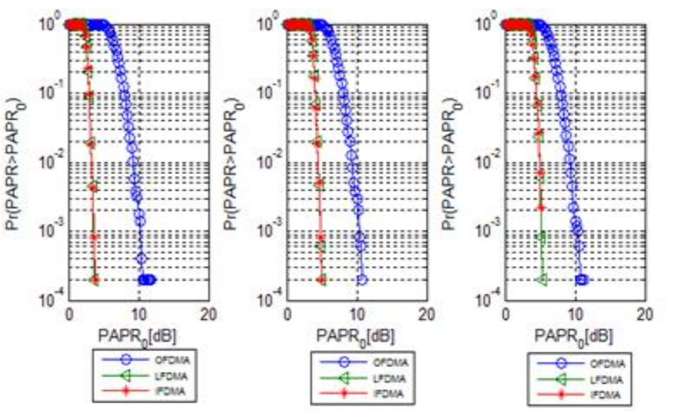


FIG 4(a)

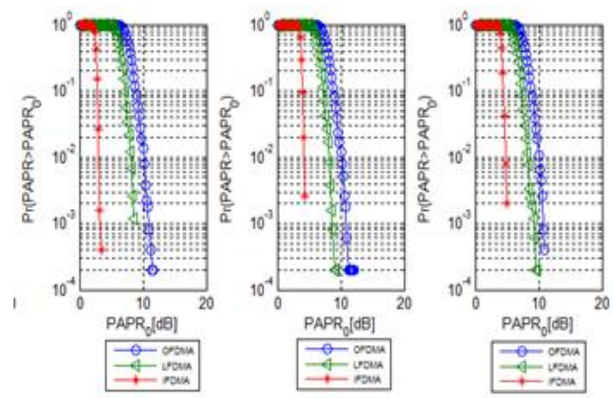


FIG 4(c)

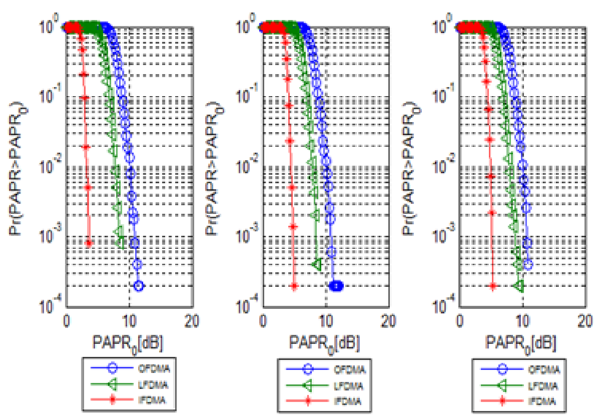
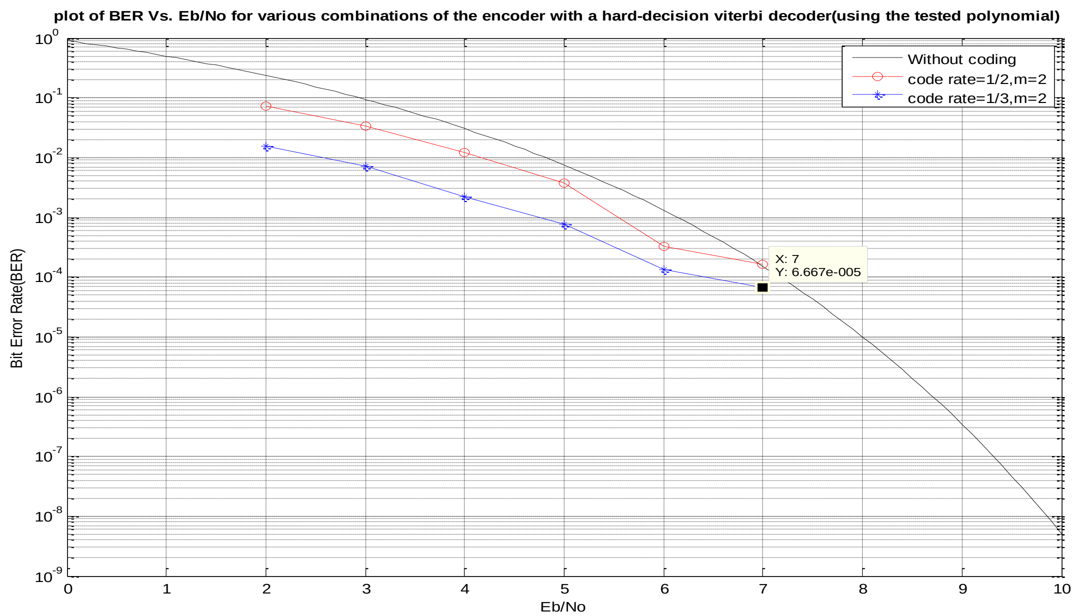


FIG 4(b)

The analysis of DFT spreading with FEC coding has been done using MATLAB. The simulation parameters considered for this analysis is summarized in table 1.

Table-1 Simulation Parameters

Sl.No	Parameters	Value
1	FFT size	64
2	Length of cyclic prefix	16
3	Modulation	QAM
4	SNR Range	2-12 dB
5	FEC Code	Convolution coding with viterbi decoding
6	DFT technique	.9



BER performance is improving for higher values of SNR

The graphs indicate that performance is improving using DFT spreading with FEC coding. Almost 5db gain is achieved.

V. CONCLUSION

OFDM systems have generic problem of high PAPR. Drawback of high PAPR is dynamic range of power amplifier and D/A convertor which increases its cost. Hence we apply reduction techniques to reduce PAPR. This paper analyzed DFT spreading technique with FEC coding. Since DFT Spreading is distortion technique and degrades bit error rate performance of system. But by using FEC coding with DFT spreading, this approach not only reducing the PAPR of the OFDM system but also improving the BER performance.

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